DOE/NV/25946--430

Development of Onsite Transportation Safety Documents for Nevada Test Site

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Abstract

Department of Energy (DOE) Orders require each DOE site to develop onsite transportation safety documents (OTSDs). The Nevada Test Site approach divided all onsite transfers into two groups with each group covered by a standalone OTSD identified as Non-Nuclear and Nuclear. The Non-Nuclear transfers involve all radioactive hazardous material in less than Hazard Category (HC)-3 quantities and all chemically hazardous materials. The Nuclear transfers involve all radioactive material equal to or greater than HC-3 quantities and radioactive material mated with high explosives regardless of quantity. Both OTSDs comply with DOE O 460.1B requirements. The Nuclear OTSD also complies with DOE O 461.1A requirements and includes a DOE-STD-3009 approach to hazard analysis (HA) and accident analysis as needed.

All Nuclear OTSD proposed transfers were determined to be non-equivalent and a methodology was developed to determine if "equivalent safety" to a fully compliant Department of Transportation (DOT) transfer was achieved. For each HA scenario, three hypothetical transfers were evaluated: a DOT-compliant, uncontrolled, and controlled transfer. Equivalent safety is demonstrated when the risk level for each controlled transfer is equal to or less than the corresponding DOT-compliant transfer risk level. In this comparison the typical DOE-STD-3009 risk matrix was modified to reflect transportation requirements. Design basis conditions (DBCs) were developed for each non-equivalent transfer. Initial DBCs were based solely upon the amount of material present. Route-, transfer-, and site-specific conditions were evaluated and the initial DBCs revised as needed. Final DBCs were evaluated for each transfer's packaging and its contents.

Purpose and Scope

The Nevada Test Site (NTS) Onsite Transportation Safety Documents (OTSDs) describe the onsite transportation of hazardous materials. The NTS approach divided all onsite transfers into two groups with each group covered by a standalone OTSD. The two groups were identified as Non-Nuclear and Nuclear. The Non-Nuclear transfers involve (a) all radioactive hazardous

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material in less than Hazard Category (HC)-3 quantities and (b) all chemically hazardous materials. The Nuclear transfers involve (a) radioactive material in equal to or greater than HC-3 quantities and (b) radioactive material mated with high explosive regardless of quantity.

As used in the OTSD, “transfer” means the movement of hazardous material from one facility to another facility within the NTS boundary. Movement within the facility yard is the responsibility of the facility and is not covered in the OTSDs. Therefore, all transfers are considered to be from gate-to-gate not dock-to-dock. Shipments moving outside the NTS boundary are offsite shipments and are not part of the OTSDs

Both OTSDs comply with the requirements of DOE O 460.1B[1], “Packaging and Transportation Safety” and follow the format specified in the Order and its associated Guide, DOE G 460.1-1[2]. The Nuclear OTSD also complies with DOE O 461.1A[3], “Packaging and Transfer or Transportation of Material of National Security Interest” and its associated Manual DOE M 461.1-1[4].

Transfers and Packagings Considered

Based on historical data, approximately 1500 onsite transfers of hazardous material are performed annually at the NTS. The materials transferred cover all nine Department of Transportation (DOT) hazard classes. The more numerous transfers involve fuels, compressed gases, and cryogenic liquids. The more frequently used packagings are Packaging Groups I, II, and III; compressed gas cylinders; cryogenic liquid containers; fuel trucks; packaging for LSA-I and II materials; packaging for SCO-I and II materials; Type A packaging for radioactive materials; and Type B(U) and B(M) packaging for radioactive materials.

The expected onsite transfers evaluated in the OTSDs may be grouped as follows:

1. Fully compliant DOT transfers. This category includes most of the onsite transfers. It includes all chemically hazardous materials, some explosives, and radioactive materials in Industrial Packaging I, II, and III and Type A and B packaging where the material quantity is within the approved packaging quantity limit. Only seven transfer types were identified that do not fit within this category and are identified below.
2. Explosives moved in compliance with the requirements in the DOE Explosives Safety Manual. Some explosives transfers are in full compliance with DOT requirements and are included in item 1 above. However, other explosive transfers are performed in accordance with the requirements in the DOE Explosive Safety Manual[5] (DOE M 440.1-1A).
3. Type B quantity of radioactive material moved in Type A packaging. Only three transfers fall in this category. These transfers involve either plutonium or cobalt in solid metal form (not powder) where the material quantity exceeds the Type A material quantity limit and the material is packaged in Type A packaging. The material quantities are precisely known – the cobalt material is a cobalt source and the plutonium materials are housed in experimental test assemblies.
4. Type B quantity of radioactive material moved in Type B packaging. This category contains only one transfer but allows five variations. The transfer involves up to 5 kg of

plutonium in any of four different Type B packagings (9975, DT-22, FL, and 6M/2R) moved individually as well as a multiple package transfer. The multiple package transfer allows for up to 25 kg to be moved at one time with any number of packages in any combination. These transfers are accompanied by an armed security escort.
5. Radioactive material mated with high explosives moved in Type A packaging. This category includes the subcritical experiment (SCE) assemblies in two different sizes identified as large and small. These transfers are accompanied by an armed security escort if the material quantity exceeds a specified amount.

The Non-Nuclear OTSD includes categories 1 and 2 and one of the transfers in category 3; the Nuclear OTSD includes the remainder.

Concept of Equivalent Safety

The principal safety objective of DOE O 460.1B and 461.1A is that the packaging and onsite transfer of materials must provide a level of protection that is substantively equivalent or identical to that provided by DOT regulations for packaging and transportation of hazardous materials. This concept of equivalent safety to DOT regulations is formulated in the Guide and Manual by establishing three categories of packaging – DOT-compliant, DOE-equivalent, and non-equivalent packaging. These terms are defined as:

1. DOT-compliant packaging is packaging that meets the regulations of DOT for offsite shipment.
2. DOE-equivalent packaging is packaging that can be shown conclusively to provide performance equivalent to packaging meeting the requirements of DOT for offsite shipment.
3. Non-equivalent packaging is any packaging that cannot be demonstrated to be either DOT-compliant packaging or DOE-equivalent packaging.

The three packaging categories have different evaluation levels. DOT-compliant packaging requires no special evaluation. DOE-equivalent packaging may be used interchangeably with DOT-compliant packaging once equivalency is established, and then requires no future special evaluation. Non-equivalent packaging requires additional evaluation that involves (a) establishing a performance envelope and specific control and communication requirements and (b) ensuring that the transfer system will operate within the performance envelope.

All of the identified onsite transfers at NTS were categorized using these definitions. The transfers identified in category 1 (fully compliant) are classified as DOT-compliant since they meet all DOT requirements. The explosives in category 2 are classified as DOE-equivalent because the requirements in the DOE Explosive Safety Manual are taken to be equal to DOT requirements. Category 3 transfers are classified as non-equivalent because the approved packaging material quantity limits are exceeded. Category 4 transfers are classified as non-equivalent instead of the expected DOT-compliant because all of the specified packaging close up steps are not performed, most notably leak testing is not performed. Category 5 transfers are classified as non-equivalent because radioactive material mated with high explosives is not allowed in public commerce under DOT regulations.

Overall Approach to Safety Assessment

A safety assessment was performed for each proposed transfer and involved the review of many factors that may impact the proposed transfer and once completed and approved, it provides the safety basis that establishes this transfer as “Routine”. These factors are discussed below. When applying the graded approach, not all of the factors discussed below apply to all transfers. Generally, all factors do not apply to the lower hazard transfers. However, all of the factors do apply to the higher hazard transfers. In addition, the higher hazard transfers may require a more detailed analysis. All of the controls derived from the safety assessment are specified in a Routine Transfer Summary.

The safety assessment may be divided into five broad areas:

1. Identify/classify the material to be transferred.
2. Evaluate the proposed packaging performance.
3. Identify/select controls.
4. Identify communication requirements.
5. Validate equivalent safety using controls.

Identify Material

The starting point for any transfer is the characteristics of the material to be moved. The first step is to identify the proposed material according to type and quantity. This information is used to determine the hazard level, the DOT Hazard Class, and, in most cases, the minimum requirements for the packaging.

Evaluate Packaging

The packaging to be used is identified. The packaging may be a choice made by the shipper (e.g., in packaging waste) or may be existing packaging (e.g., waste is already packaged). The packaging should be categorized as DOT-compliant, DOE-equivalent, or non-equivalent. The packaging and proposed material contents are evaluated jointly to determine if the package is DOT-compliant, DOE-equivalent, or non-equivalent.

The packaging evaluation process may be divided into four main steps:

1. Identify the DOT-authorized packaging using the information provided in the Hazardous Material Table (49 CFR 172.101[6], Table 172.101). Column 3 in the table provides the hazard class, Column 5 identifies the required Packing Groups (PGs), and Column 8 provides a reference to the appropriate 49 CFR 173[7] packaging subsection for each material. Column 7 lists any special provisions and must be checked to ensure that all packaging requirements are known. The designated PG and the cited CFR section identify the DOT packaging requirements.
2. Determine if the packaging meets the requirements identified in the above step. The packaging must meet the specific requirements of Part 173 as referenced in the

Hazardous Materials Table. In addition, packaging must meet the general requirements of 49 CFR 173.24 through 173.26. Packaging meeting more stringent requirements may be used. If the packaging meets these requirements, then the package is DOT-compliant. The follow-on step is to determine if the onsite handling and normal conditions of transport are more severe than those encountered in offsite commerce. If these site-specific conditions are not more severe (which should normally be the case), then the packaging evaluation is complete and it is only necessary to identify the controls and communication requirements as discussed below.

3. If the packaging is not DOT-compliant, then it is necessary to consider if the packaging satisfies the specific requirements of an applicable Offsite Transportation Authorization (OTA) or Offsite Transportation Certificate (OTC). If the packaging meets these requirements, then determine if the onsite handling and normal conditions of transport are more severe than those encountered offsite. If these site-specific conditions are not more severe (which should normally be the case), then the packaging evaluation is complete and it is only necessary to identify the controls and communication requirements as discussed below.
4. If the packaging does not satisfy either Step 2 or 3, the packaging is non-equivalent and a more detailed evaluation is required. This detailed evaluation requires the establishment of design basis conditions (DBCs) and a performance envelope for the packaging. This process is discussed later. If the non-equivalent package evaluation demonstrates an equivalent level of safety, it is only necessary to identify the controls and communication requirements as discussed below.

Identify/Select Controls

The controls to be imposed on the transfer must be identified. The controls need only ensure that the packaging will not be exposed to transportation conditions any more severe than those the packaging would experience during an offsite shipment. The packaging evaluation identified the differences between the proposed packaging and the DOT-authorized packaging. The selected controls must address those differences and result in achieving an equivalent level of safety. Typical controls that may be imposed are restrictions on the transport vehicle or type, vehicle refueling, driver qualifications, escort vehicles, road closures, speed limits, load makeup, loading/unloading operations, package stacking, load securement, and weather conditions. Additional controls may be required for specific transfers based on their individual and unique circumstances.

Identify Communication Requirements

The communication requirements applicable to onsite hazardous material transfer activities must be identified. The purpose of the DOT communication requirements is to inform personnel as to the contents of the package and/or vehicle and thus to any hazards the cargo poses during routine handling or accident conditions. Typical communication requirements include package marking and labeling, vehicle placarding, shipping papers, emergency contact information, and prior notifications.

Validate Equivalent Safety Using Controls

After the controls and communications have been selected, the transfer system (packaging, controls, and communications) must be re-evaluated to determine if an equivalent level of safety has been achieved. If there remains unmitigated risk, additional controls must be identified and analyzed. Once an equivalent level of safety has been achieved, the established method of transfer has been defined.

The desired goal of the safety assessment process is to allow fully DOT compliant transfers to quickly “fall out” of the evaluation process. The remaining transfers are typically non-equivalent and additional evaluation is required. The additional evaluation steps are discussed in the remaining sections of this paper.

Establishing Design Basis Conditions and Performance Envelopes

A performance envelope was established for each non-equivalent transfer. The performance envelope consists of the design basis conditions (DBCs) for the packaging and any other transfer specific condition that must be addressed. The process is performed as follows.

1. The initial DBCs are established. The initial DBCs are based solely upon the amount of material present. For all the Nuclear OTSD transfers considered here, this was always a Type B material quantity and the initial DBCs were always the general Type B packaging test requirements specified in 10 CFR 71.71[8] and 71.73. If only Type A material quantity is involved, then the initial DBCs would be the general Type A packaging test requirements specified in 49 CFR 173.465.
2. The offering and receiving facilities were identified and the transfer route specified. These items set the stage for route- and site-specific evaluations.
3. The route-, transfer-, and site-specific conditions were evaluated and any conditions or hazards that exceed what is expected by DOT or require modification of the initial DBCs are identified.
4. The final DBCs are established. The final DBCs consist of the initial set plus any required modifications due to route-, transfer-, or site-specific conditions. The results of this step constitute the performance envelope.
5. The final DBCs are evaluated. The evaluation is based on the packaging and its contents as a linked pair.

The process involved in the first four steps is illustrated in the following two examples – (a) a transfer involving 2 kg of Pu-239 in solid metal (not powder) form in a Type B packaging and (b) a transfer involving 0.2 kg Pu-239 in solid metal (not powder) form in a Type A packaging.

Initial DBCs: The proposed material in both examples exceeds the A_2 value (defined in 49 CFR 173.435) for plutonium of 0.435 g and is considered a Type B material quantity. Therefore impose Type B DBCs on the packaging since Type B material quantity is involved. Plutonium is a fissile material and the fissile packaging requirements (specified in 10 CFR 71.55 and by reference in 71.43, .45, and .47) are applicable. The initial DBCs are (a) Type B DBCs on packaging since Type B material quantity is involved and (b) fissile packaging requirements since fissile material is involved.

Route Specific Hazards: Once the propose transfer route is identified it can be evaluated. Generally the proposed transfer route will contain no road or roadside hazard that is not typically encounter on public roads. Therefore, it is possible to state that (a) the route poses no additional hazards and the comparison of being equal to DOT is fulfilled and (b) thus, the CFR Type B test requirements are adequate and do not need to be modified. The foregoing general statements may be made because the public roads contain a wide variety of conditions – (a) two-lane roads, four-lane roads, interstate highways, and city streets; (b) rural and urban road intersections with two-way and four-way stop signs, yield signs, and traffic lights; (c) side roads, driveways, and business entrances; (d) bridges, bridge abutments, utility poles, and embankment drop-offs; and (e) roadside gasoline, diesel, and propane fuel stations and electric substations. Also, it is important to remember that the onsite route hazards are not identified in an absolute sense but only to the extent that they exceed what is encountered on the public roads.

Transfer Specific Hazards: At the NTS only two specific hazards were identified for selected transfers.

1. Certain transfers involved a sufficient quantity of material that the transfer required an armed security escort. In these cases, the armed security personnel and their weapons are a potential hazard that is not present on public roads. For the examples cited here, it is assumed the 2 kg transfer would require the security escort and the 0.2 kg transfer would not.
2. Certain transfers involve large fissile material quantity where the exact shape, isotropic content, and other details are not known. A potential for an inadvertent criticality exists. For the examples cited here, criticality is not a concern due to the limited material quantity and its solid metal form. If the material quantity were changed to say 5 kg then criticality would be a concern. This 5 kg variation will be carried forward for illustration purposes.

Site Specific Hazards: The temperatures extremes at the NTS generally are different than those specified in the general Type B test requirement. Specifically:

1. The specified extreme hot temperature is 38°C (100°F). A more reasonable maximum hot temperature is 115°F (46°C), the maximum value recorded on the NTS. Use a value of 115°F (46°C).
2. The specified extreme cold temperature is -40°C (-40°F). A more reasonable minimum cold temperature is 10°F to 20°F (-12°C to -7°C); the minimum value recorded at Mercury is 11°F (-12°C). Use a value of 10°F (-12°C).

Final DBCs: For the 2 kg example, impose (a) Type B DBCs on package with modified hot and cold temperatures, (b) fissile packaging requirements, (c) armed security personnel weapon hazard, and (d) criticality hazard (allowing for the 5 kg variation). For the 0.2 kg example, impose (a) Type B DBCs on package with modified hot and cold temperatures and (b) fissile packaging requirements.

Evaluating Package Performance

Once the DBCs and performance envelope are know, the package performance is evaluated. The evaluation process is illustrated for the two examples cited. It may be useful to use specific packaging for the evaluation phase. Thus, assume the Type B packaging is a 9975 packaging and the Type A is a TRUPACT-II standard waste box (SWB). The 9975 is certified as fissile packaging; the SWB is vented.

For the 2 kg example:
(a) Type B DBCs – Type B packaging is used for the transfer. Type B packaging by virtue of its certification meets all of the Type B DBCs except the new extreme temperatures. The new extreme cold temperature is warmer than that specified in the Type B test requirements and is thus automatically satisfied. The new extreme hot temperature is warmer than that specified in the Type B test requirements but the packaging is not susceptible to this relatively small temperature increase because the packaging successfully passes the required thermal test. Therefore, the new hot temperature requirement is satisfied. No further evaluation of the Type B test requirements is required.

(b) Fissile Packaging Requirements – The Type B packaging used is certified for fissile material and thus the fissile packaging requirements are automatically satisfied.

(c) Armed Security Escort – These concerns are addressed in the OTSD but are not discussed here.

(d) Criticality – For the 5 kg variation, a criticality safety evaluation is required for each transfer. Therefore, an inadvertent criticality, and hence the criticality hazard is prevented. The requirement for a criticality safety evaluation is a transfer specific imposed control.

Thus, all of the final DBCs are satisfied for the 2 kg example.

For the 0.2 kg example:
(a) Type B DBCs – Type A packaging is used for the transfer. Type A packaging does not meet all of the specified Type B DBCs. Therefore, further evaluation is required.

The Type B DBCs are evaluated in Table 1 below. The table presents a summary of the Type B test requirements specified in 10 CFR 71.71 for normal conditions of transport (NCT) and 71.73 for hypothetical accident conditions (HAC). The Type A test requirements are specified in 49 CFR 173.465. In the evaluation process, the known or expected performance of packaging and its contents is evaluated for each test requirement.

Table 1. Evaluation of Type B DBCs for the 0.2 kg Case Type A Packaging.

Test Condition	Metric Units/ In-lb Units	Evaluation
NCT		
Water Spray	5 cm/hr for 1 hr 2 in/hr for 1 hr	Pass. Same as Type A requirements. However, could be not applicable if package is not exposed to weather or water. If so, this would be a site-specific control.
Free Drop	0.3 to 1.2 m, varies w/ weight 1 to 4 ft, varies w/ weight	Pass. Same as Type A requirements.
Corner Drop	0.3 m 1 ft	Pass. Same as Type A requirements.
Stacking (Compression)	5x weight or 13 kPa, 24 hrs 5x weight or 2 psi, 24 hrs	Pass. Same as Type A requirements. However, could be not applicable if package is not stacked. If so, this would be a site-specific control.
Penetration	3.2 cm dia, 6 kg bar, falling 1 m 1.25 in dia, 13 lb bar, falling 40 in.	Pass. Same as Type A requirements.
Vibration	1.6 mm bounce for 1 hr 0.063 in bounce for 1 hr	Pass. Type A packaging is not susceptible to vibration in this range. The solid form of the contents is not susceptible to vibration in this range.
Hot	38°C 100°F	Pass. Extreme hot temperature is changed to 115°F (46°C). Example packaging is not susceptible to temperatures in this range.
Cold	-40°C -40°F	Pass. Extreme cold temperature not applicable to NTS. Extreme cold temperature is changed to 10°F (-12°C). Example packaging is not susceptible to temperatures in this range.
Reduced External Pressure	25 kPa 3.5 psi	Not applicable. Example packaging is vented. However, if the package is not vented, a potential source for the pressure differential must be identified or the requirement is not applicable.
Increased External Pressure	140 kPa 20 psi	Not applicable. Example packaging is vented. However, if the package is not vented, a potential source for the pressure differential must be identified or the requirement is not applicable.
HAC		
Free Drop	9 m 30 ft	Example packaging will not maintain confinement after drop. However, the Pu solid form and the zero release fraction for impact, results in acceptable consequences.
Crush	500 kg, falling 9 m 1100 lb, falling 30 ft	Bounded by free drop. See discussion at free drop.
Puncture	Falls 1 m onto 15 cm bar Falls 40 in onto 6 in dia bar	Bounded by free drop. See discussion at free drop.
Thermal	800°C for 30 min 1475°F for 30 min	Example packaging will not survive the fire. However, the Pu solid form and the low release fraction for fire, results in acceptable consequences. In fact, the fraction released (0.050 g) is less than the allowable leak rate for a Type B package of less than an A_2 value

		(0.435 g).
Water Immersion	15 m water head 50 ft water head	Not applicable. There is no water source along the route. Criticality is not an issue due the small amount of material present.

The airborne release fraction (ARF) and respirable fraction (RF) for plutonium in solid metal form are given in DOE-HDBK-3010[9] and are zero for impact or mechanical insults and 5E-3 and 0.5, respectively, for thermal insults. The combined thermal value is 0.25E-3 and for 200 g of total material, the released amount is only 0.050 g. By comparison, the A_2 value for plutonium is 0.435 g. The Type B acceptance criterion is that the allowable leak rate must be less than an A_2 value in one week. Thus, one may conclude that the Type A packaging with a postulated 200 g of plutonium in solid metal form has a lower leak rate (0.050 g) than the acceptance criterion for Type B packaging (0.435 g) and that the consequences from any accident would not be more severe that what is accepted by DOT on the public roads. In this manner, this transfer involving this specific packaging and its specific contents demonstrates a level of safety that is equivalent to (in this case better than) that accepted by DOT for public commerce. Thus, it is concluded that the packaging and contents meets the Type B DBCs. Note that this conclusion is based on both the packaging and contents as a linked pair.

(b) Fissile Packaging Requirements – The Type A packaging used does not specifically address fissile material requirements and further evaluation is required. The fissile packaging requirements may be evaluated in a table as was shown for the Type B test requirements. Most requirements concern packaging dimensions, fastening devices, lifting fixtures, and tie-down devices. These requirements are easily addressed once the packaging details are known. The criticality requirements in 10 CFR 71.55 are primarily concerned with packaging robustness or rigidity such that the contents would be subcritical. In the 0.2 kg example, these requirements are not applicable because the package contents are limited to 200 g of plutonium in solid form and are subcritical without assistance from the packaging. This will generally be the case or the potential for a criticality exists and the packaging cannot be used. Thus, the example Type A packaging containing 200 g of plutonium passes all applicable requirements. Again, note that this conclusion is based on both the packaging and contents as a linked pair.

Transportation Hazard Analysis

A transportation hazard analysis (THA) was applied to non-equivalent transfers to help demonstrate safety equivalence and to identify necessary controls. The THA process used is similar to the Process Hazards Analysis (PrHA) commonly associated with DOE-STD-3009[10]. The major steps in the process are to identify: (a) the type, quantity, and form of the material to be moved, (b) the offering and receiving facilities, (c) the transfer route and its length, (d) the number of transfers per year, (e) the packaging to be used and its pedigree, and (f) the transfer vehicle to be used. Each route was evaluated to identify any route-specific hazards and the overall transfer was evaluated to identify any transfer-specific hazards. These initial hazards were subjected to a screening process and the remaining hazards were the basis for the transportation accident scenarios considered. For each THA scenario, the frequency of the event, the associated consequence, and the resulting risk were determined. The unique aspects of the THA are a modified risk matrix adapted to transportation needs, truck accident frequency calculations, and an alternate method of demonstrating equivalent safety. These items are discussed below.

Modified Risk Matrix

The risk matrix shown in Table 2 was used. The risk matrix is similar to the typical DOE-STD-3009 risk matrix but was modified to reflect the objective of DOE M 461.1-1 to limit radiation exposures to 5 rem for creditable accidents. Given that consequence categories A and B represent doses in excess of 5 rem, and assuming that credible accidents have a frequency of at least 1 x 10^{-6}/ year (frequency categories I, II, and III), the corresponding risk bins were deemed “high risk” and thus assigned a risk index of “1”. Consequence category C represents doses less than 5 rem; this consequences level is acceptable and is assigned a risk index of “3.” Consequence category D represents even lower doses and is assigned a risk index of “4.” Excluded from the risk matrix are consequence/frequency combinations assigned to a risk index of “2” (medium risk – marginal). The omission of risk index “2” is a direct result of the 5-rem threshold established in DOE M 461.1-1 for credible accidents.

Table 2. Risk Determination Matrix.

Consequence Category	Frequency Category			
	I ($>10^{-2}$)	II (10^{-2} - 10^{-4})	III (10^{-4} - 10^{-6})	IV ($< 10^{-6}$)
A	1	1	1	3
B	1	1	1	3
C	3	3	3	3
D	4	4	4	4

1 – High Risk – Unacceptable
3 – Low Risk – Acceptable
4 – Negligible Risk - Acceptable

Generic Transportation Accidents and Their Frequencies

Many potential truck accidents are mileage-based, where the likelihood of an accident is dependent on the distance traveled. Data associated with these types of accidents on public roadways are routinely gathered and analyzed by various state and federal agencies. These data are often used to construct accident event trees. These event tree models can be used to estimate frequencies for specific types of accident scenarios. These frequency estimates can in turn provide a basis for making frequency bin assignments to individual THA accident scenarios.

Transportation Accident Event Tree. Existing truck accident data and their detailed event tree models[11,12,13] were reviewed. These detailed models were simplified and a suitable mileage-based event tree model was developed for evaluating NTS THA vehicle accident scenarios that preserved sufficient fidelity to ensure that important controls could be derived from the retained accident categories. The simplified event tree is shown in Figure 1. The event tree is divided across the top into a set of headings. The split fractions for the branches under each heading were based on the summation of corresponding constituent split fractions from the more detailed event trees and do not always sum to exactly 1.000 due to rounding. The split fractions represent the fraction of the time or likelihood that a given event occurs. For example, the event tree indicates that of all tuck accidents, 74.1% are due to a collision of some sort, of these 88.1% involve collision with a vehicle (“non-fixed object”), and of these 2.1 % are due to head-on collisions.

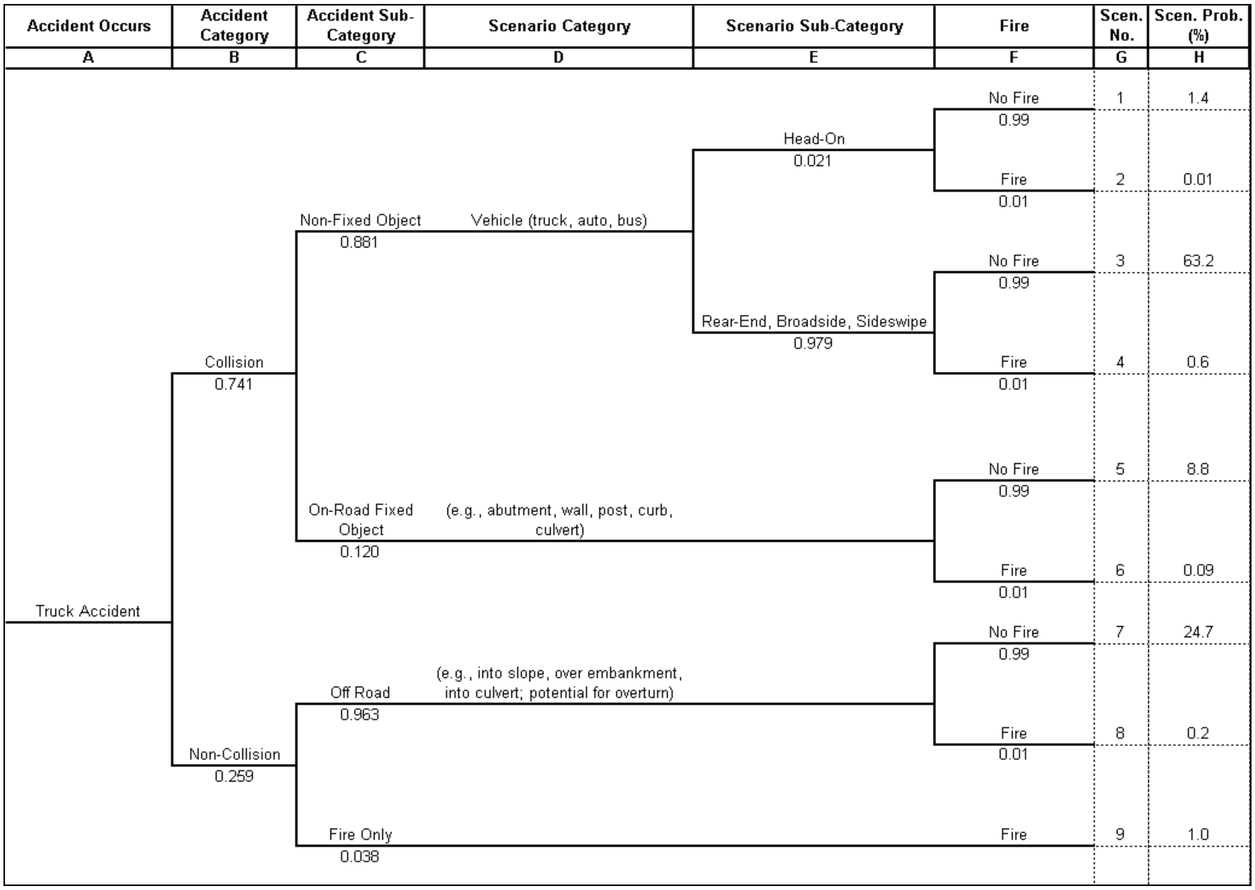

Figure 1. Event Tree for NTS Transportation Accidents.

Truck Accident Rate. Eight existing truck accident rate studies[11,12,14-19] covering the time period from 1968 to 1999 were reviewed to determine an appropriate baseline truck accident rate on a per mile basis. Although the definition of what constitutes an accident and what types of highways are included differ from study to study, the accident rates vary from 6.4E-06 to 4.7E-08/mi (4.0E-06 to 2.9E-08/km) and all but two reported values are less than about 5E-07/mi (3E-07/km). A baseline value of 5E-07/mi (3E-07/km) was adopted and is the value reported by reference 13. This value was increased by a factor of 10 to help bound the potential effects of various uncertainties. The factor of 10 is referred to as the “supplementary uncertainty factor.”

Example Traffic Accident Frequency Calculation. The traffic accident frequency associated with a given THA scenario combines the baseline accident rate with the event tree split fraction as follows. Assume the THA scenario involves a head-on collision without a follow-on vehicle fire, the transfer route is 10 miles, and there are five transfers per year. The route accident frequency (for any type of accident) is based on the product of (a) the baseline truck accident rate of 5E-07/mile, (b) the 10-mile route distance, (c) five transfers per year, and (d) the supplementary uncertainty factor of 10. The resulting value is (5E-07 accidents/mile) (10 miles/trip) (5 trips/year) (10) and is 2.5E-04 accidents/year. The conditional probability that the accident is a head-on collision without vehicle fire is the product of the accident is a collision (0.741 from column B), involves a vehicle (0.881 from column C), is a head-on collision (0.021 from column E), and no fire (0.99 from column F) or 0.0136. The desired frequency is the product of the frequency that an accident occurred (2.5E-04 accidents/year) and the conditional probability that the accident was a head-on accident without fire (0.0136) or 3.4E-06 events/year which corresponds to frequency bin III.

THA Scenarios

THA scenarios were developed for the proposed Nuclear OTSD transfers. The scenarios are organized by transfer route. Consequences and resulting risks were determined for the immediate worker, the co-located worker at a distance of 100 meters, and the public located at the closest distance to the site boundary. For each THA scenario, three difference hypothetical transfers were evaluated – a DOT-compliant transfer, an uncontrolled transfer, and a controlled transfer. The DOT-compliant transfer represents a shipment over the public roadways for which all DOT controls are applied. Consequence category “C” (less than 5 rem) is assigned to this transfer. The uncontrolled transfer represents a transfer on the NTS that assumes no credit for the post-accident integrity of the packaging and no credit for load securement. Credit for these items was not taken in the uncontrolled case to determine if the credit and the resulting controls were required. The consequence category was determined using scoping dose consequence estimates. The controlled transfer represents the proposed on-site transfer with risk profile based on an identified suite of controls. The consequence category was determined using scoping dose consequence estimates. The risk profile associated with the controlled transfer provides a safety metric for the movement of material on the NTS.

Equivalent Safety Determination Based on Risk

The evaluation to determine if equivalent safety is achieved is based on the risk indices derived from the individual THA scenarios. Within a given THA scenario, risk measures for the controlled transfer were compared with the corresponding risk measures for the hypothetical DOT-compliant transfer. In this context, equivalent safety is demonstrated if each controlled transfer has a risk level that is the same or less than the risk level for its corresponding DOT-compliant transfer. The comparison of risk indices was made for each scenario and all three receptors – immediate worker, co-located worker, and public. In all cases, an equivalent level of risk was demonstrated or additional controls were imposed to reduce the risk to an equivalent level, or an equivalent level of risk was not demonstrated and residual risk remains and must be accepted or the as proposed transfer not performed.

Summary and Conclusions

The NTS OTSDs comply with the requirements of DOE O 460.1B and 461.1A. These OTSDs provide the bases for performing transportation safety evaluations that are significantly different than the traditional safety evaluations performed for facilities. The major differences and unique aspects of the transportation safety evaluation and areas discussed are:

1. The safety objective is not a "hard" target but is a "soft" target of demonstrating a level of safety equivalent to that provided by DOT regulations.
2. Two different methods of demonstrating equivalent safety were developed – (a) a deterministic method based on the postulated amount of material expected of being released in an accident and its comparison to a DOT acceptable leak rate and (b) a risk method based on a comparison of risk indices for hypothetical DOT-compliant and controlled THA scenarios.
3. The development of DBCs and performance envelopes for the proposed transfers.
4. The modification of generic DBCs for site-specific conditions.
5. The evaluation of specific packaging and its contents as a linked pair against the associated DBCs and performance envelope.
6. The development and use of a risk matrix tailored to transportation activities.
7. The development and use of truck accident rates based on national highway date and an accident event tree.

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